भारतीय मानक
Indian Standard

IS 1180 (Part 3) : 2021

बाहय/आंतरिक-रंग तरल इम्मेर्सड वितरण ट्रांसफार्मर तक 2 500 kVA, 33 kV — विशिष्टि

भाग 3 प्राकृतिक/संश्लेषित कार्बनिक एस्टर तरल निमिज्जित

Outdoor/Indoor Type Liquid Immersed Distribution Transformers Up to and Including 2 500 kVA, 33 kV — Specification

Part 3 Natural/Synthetic Organic Ester Liquid Immersed

ICS 29.180

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FOREWORD

This Indian Standard was adopted by the Bureau of Indian Standards, after the draft finalized by the Transformers Sectional Committee, had been approved by the Electrotechnical Division Council.

This standard specifies the requirements of natural/synthetic organic ester liquid immersed distribution transformers. This standard is a part of IS 1180 series on distribution transformers. Other standards in this series are:

Part 1 Mineral oil immersed

IS 1180 (Part 1) : 2014 specifies requirements for mineral oil immersed outdoor/indoor type three phase distribution transformers up to 2 500 kVA, 33 kV and single phase distribution transformers up to 100 kVA, 33 kV. A note under **9.1** of IS 1180 (Part 1) allowed use of other insulating liquids namely natural ester, synthetic organic ester subject to agreement between the user and the supplier.

However, it was also mentioned in the foreword of IS 1180 (Part 1) that when sufficient experience of ester liquids would be available, separate standard on distribution transformers filled with natural/synthetic organic esters shall be brought out. In the intervening period, several distribution transformers have been filled/retro filled with esters and a few power transformers have also been developed using esters. A need is now felt to have a separate standard on natural/synthetic organic ester liquid immersed distribution transformers.

The main advantage of ester liquid is its higher fire point (above 300 °C) compared to that of mineral oil. The use of ester liquid with fire point above 300 °C has increased in several countries due to fire safety and environmental considerations.

Being 'K' class liquid having fire point above 300 °C, this liquid can work on higher temperature rises with compatible high temperature insulation material. This standard also explores such possibility based on IS 2026 (Part 14) 'Liquid-immersed power transformers using high temperature insulation materials'.

This standard also permits use of conventional insulation with ester liquids and temperature rises for the same have also been specified.

This standard specifies five energy efficiency levels: level 1, level 2, level 3, level 4 and level 5. Maximum total losses for each level (at 75 ºC) have been kept same as given in IS 1180 (Part 1). In due course of time with improvements in technology and materials, higher levels of energy efficient transformers shall be progressively used.

Pad mounted distribution transformers are popular in other countries. They are self-protected and obviate the need of ring main unit as used in prefabricated compact substations up to 33 kV. Such pad mounted distribution transformers are also suggested for use in the country up to 33 kV filled with ester liquids. When sufficient experience builds a separate standard in IS 1180 series can be developed for Pad mounted transformers.

At present, there is no IEC standard available on ester liquid immersed distribution transformers. However, considerable assistance has been taken from following standards while preparing this standard:

IS 16659 : 2017	Fluids for electrotechnical applications — Unused natural esters for transformers and similar electrical equipment
IS 16081 : 2013	Insulating Liquids — Specification for unused synthetic organic esters for electrical purposes
IS 2026 (Part 14) : 2018	Power transformers (Part 14) Liquid immersed power transformers using high-temperature insulation materials

IS 1180 (Part 1) : 2014 is a necessary adjunct to this standard.

For the purpose of deciding whether a particular requirement of this standard is complied with the final value, observed or calculated, expressing the result of a test or analysis shall be rounded off in accordance with IS 2 : 1960 'Rules for rounding off numerical values (*revised*)'. The number of significant places retained in the rounded off value should be the same as that of the specified value in this standard.

Indian Standard

OUTDOOR/INDOOR TYPE LIQUID IMMERSED DISTRIBUTION TRANSFORMERS UP TO AND INCLUDING 2500 kVA, 33 kV — SPECIFICATION

PART 3 NATURAL/SYNTHETIC ORGANIC ESTER LIQUID IMMERSED

1 SCOPE

This standard specifies the requirements and tests including standard loss levels of natural/synthetic organic ester liquid immersed, natural air-cooled, outdoor/indoor type, double-wound distribution transformers for use in power distribution systems with nominal system voltages up to and including 33 kV and of following types and ratings:

a) Three phase ratings up to and including 200 kVA both non-sealed and sealed type;

b) Three phase ratings higher than 200 kVA, up to and including 2 500 kVA both non-sealed type and sealed type; and

c) Single phase ratings up to and including 100 kVA sealed type.

This standard permits use of natural esters as well as synthetic organic esters in both non-sealed and sealed type of transformers. However, in case of non-sealed type transformers immersed in natural ester, suitable liquid preservation system such as airbags shall be used in the conservator to prevent direct contact of natural ester with the atmosphere.

NOTES

1 The following types of transformers are not covered under the scope of this standard:

a) Inverter duty transformers;

b) Traction transformers;

c) Instrument transformers;

d) Transformers for static converters;

e) Starting transformers;

f) Testing transformers;

g) Welding transformers;

h) Earthing transformers;

j) Mining transformers;

k) Transformers for solar, wind power application;

m) Transformers for railways (locomotive and other applications);

n) Furnace transformers;

p) Rectifier transformers;

q) Dual ratio in primary/secondary windings transformers; and

r) Transformers for Static VAR compensator.

2 Forindoor type distribution transformers, relevant provisions of Central Electricity Authority (CEA) Regulations, if any, shall be applicable.

2 REFERNCES

The standards listed in Annex A contain provisions which, through reference in this text, constitute provisions of this standard. All standards are subject to revision, and parties to agreements based on this standard are encouraged to investigate the possibility of applying the most recent editions of the standards listed in Annex A.

Annex B gives a list of IEC standards, IEEE standards, CIGRE brochures etc. available on ester liquids.

3 TERMINOLOGY

For the purpose of this standard, the following terms and definitions shall apply in addition to those given in IS 1885 (Part 38).

3.1 Distribution Transformer — A distribution transformer is a transformer that provides the final voltage transformation by stepping voltages down within a distribution circuit or from a distribution circuit to an end user or application.

NOTE — The distribution circuit voltages are 3.3 kV, 6.6 kV, 11 kV, 22 kV and 33 kV in the country. The power supply for the end users is 415 V, 3 Phase (240 V, 1 Phase), 50 Hz. Transformers with primary voltages of 3.3, 6.6, 11, 22 or 33 kV and secondary voltage of 433 V, 3 Phase (and 250 V single Phase) are called Distribution Transformers. The maximum rating of these transformers for the purpose of this standard is considered up to 2 500 kVA, 3 Phase.

3.2 Non-Sealed Type Transformer — A transformer which has a breather for breathing out and breathing in and/or a conservator with expansion and contraction of liquid with temperature. The transformer tank body and cover are bolted/clamped/welded type. The tank can also be of corrugated construction.

Transformers equipped with suitable liquid preservation system such as airbags, which prevents direct contact of atmosphere with the liquid in the conservator, are covered under the category of non-sealed type transformers.

3.3 Sealed Type Transformer — A transformer which is non-breathing, that is, so sealed that normally there is no significant interchange between its contents and the external atmosphere. No conservator is provided. Such

a transformer may or may not have a cushion of inert gas (for example, nitrogen, IS 1747).

Sealed transformers fall into two categories:

a) Transformers in which the total volume of liquid together with inert gas/nitrogen or any combination thereof, remains constant over the temperature range.

b) Transformers in which the total volume of liquid, inert gas/nitrogen or any combination thereof, varies over the temperature range and this variation is accommodated by a sealed flexible container (corrugated tank) or a flexible membrane

Sealed type transformers usually have a bolted/clamped/welded cover construction.

3.4 'K' Class Insulating Liquids — According to IS 13503, liquids with fire point above 300 °C are classified as K class liquids. Synthetic organic ester, natural ester and silicon liquids come under this category.

Percentage of biodegradability of silicone liquid is low (around 5 percent). For the purpose of this standard, only synthetic esters and natural esters which are 80 to 100 percent biodegradable are considered.

3.4.1 *Natural Esters* — Vegetable oils obtained from seeds and oils obtained from other suitable biological materials and comprised of triglycerides are called natural esters.

Suitable chemical substances called additives are deliberately added to natural ester insulating liquids in order to improve certain characteristics, *for example* pour point, viscosity, foaming and oxidation stability.

NOTE — Examples of additives include antioxidants, pour-point depressants, refining process improver, coloure etc.

Natural esters are recommended only for transformers that are not open to the atmosphere (for example, sealed transformers, non-sealed transformers with suitable liquid preservation system which prevents direct contact of atmosphere with the liquid in the conservator) because these liquids are prone to rapid oxidation.

NOTE — For guidance on use and maintenance of natural esters, IS 16659 and IS 16899 may be referred.

3.4.2 *Synthetic Organic Esters* — By definition, an ester is a reaction product from the combination of an acid and an alcohol. Synthetic organic esters are manufactured from carefully selected raw materials to give a product that is tailored to specific application of transformers blended with additives to improve certain characteristics, *for example*, pour point, viscosity, foaming, oxidation stability making it suitable for the breathing system where the liquid has free access to oxygen from air.

Synthetic organic esters are suitable for non-sealed and sealed transformers without any preservation system.

NOTE — For guidance on use and maintenance of synthetic esters, IS 16081 and IS 16099 may be referred.

3.5 Pad Mounted Transformer — An outdoor transformer utilized as part of underground distribution system with enclosed compartment(s) for high voltage and low voltage cables entering from below and mounted on a foundation pad.

The pad mounted transformer generally covers two bushings and terminal arrangements for radial feed systems. It consists of a tank with high voltage and low voltage cable terminating compartments separated by a barrier of metal or other rigid material. These compartments are located side by side on one side of the transformer tank. The transformer shall be of sealed construction.

4 SERVICE CONDITIONS

The provisions of IS 2026 (Part 1) shall apply.

NOTE — In case of indoor type transformers and transformers installed in an enclosure, suitable ventilation, if required, shall be provided to maintain service conditions as per IS 2026 (Part 1).

5 GENERAL

Technical parameters including standard loss levels of three categories of distribution transformers are given in **6**, **7** and **8**.

Other requirements as described in **9** to **22** are applicable for all types and ratings of distribution transformers.

6 TECHNICAL PARAMETERS OF THREE PHASE DISTRIBUTION TRANSFORMERS UP TO AND INCLUDING 200 KVA (NON-SEALED AND SEALED TYPE)

6.1 Ratings

The standard ratings shall be as per Table 1.

6.2 Rated Frequency

The rated frequency shall be 50 Hz.

Table 1 Standard Ratings

(*Clause* 6.1)

Sl No.	Nominal System Voltage	Standard Ratings (kVA)
(1)	(2)	(3)
i)	Up to and including 11 kV	*6.3, *10, 16, *20, 25, *40, 63, 100, 160 and 200
ii)	Above 11 kV up to and including 22 kV	*6.3, *10, 16, *20, 25, *40, 63, 100, 160 and 200
iii)	Above 22 kV up to and including 33 kV	*6.3, *10, 16, *20, 25, *40, 63, 100, 160 and 200

NOTE — * ratings are non-preferred.

6.3 Nominal System Voltage

Nominal system voltage shall be chosen from the following:

High Voltage (HV) — 3.3, 6.6, 11, 22 and 33 kV

Low Voltage (LV) — 415 V

6.4 Basic Insulation Level (BIL)

Minimum basic insulation level shall be as given in Table 2.

Table 2 Minimum Basic Insulation Level

(*Clause* 6.4)

Sl No.	Nominal System Voltage (kV)	Minimum BIL (kV_p)
(1)	(2)	(3)
i)	3.3	40
ii)	6.6	60
iii)	11	75
iv)	22	125
v)	33	170

NOTE — Insulation coordination of all relevant fittings and accessories corresponding to higher BIL values shall be ensured.

6.5 No-Load Voltage Ratios

The no-load voltage ratios shall be as follows:

3 300/433-250, 6 600/433-250, 11 000/433-250, 22 000/433-250 and 33 000/433-250 V

NOTE — Secondary voltage may be selected as 415-240 V, subject to agreement between the user and the supplier.

6.6 Winding Connections and Phase Displacement

The primary winding shall be connected in delta and the secondary winding in star [vector symbol, Dyn 11 (*see* IS 2026 Part 1)], so as to produce, a positive phase displacement of 30° from the primary to the secondary vectors of the same phase. The neutral of the secondary winding shall be brought out to a separate insulated terminal.

Alternatively, [Dyn1, *see* IS 2026 (Part 1)] can also be specified. If system and application requirements demand different vector groups, the same can also be adopted.

6.7 Tapping Range and Tapping Methods

6.7.1 No taps are normally required to be provided up to 100 kVA rating, unless specifically specified by the user.

6.7.2 The standard tapping range, when taps are provided above 100 kVA rating shall be as follows:

Winding tapped	—	HV
Number of tap positions	—	4
Voltage variation	—	+2.5 percent to −5 percent of HV in steps of 2.5 percent

6.7.3 Off circuit tap-changing arrangement shall be either by means of links or by means of an externally-operated switch with mechanical locking device and a position indicator. Arrangement for pad-locking shall be provided.

6.7.4 Provision of any other tapping range and tapping step is subject to agreement between the user and the supplier.

6.8 Losses and Impedance Values

6.8.1 *Losses — Multiple Rating with Regard to Energy Efficiency*

6.8.1.1 For transformers of HV voltage up to 11 kV, the total losses (no-load + load losses at 75 °C) at 50 percent of rated load and total losses at 100 percent of rated load shall not exceed the maximum total loss values given in Table 3.

6.8.1.2 For transformers having voltage class above 11 kV and up to and including 22 kV, the permissible total loss values shall not exceed by 5 percent of the maximum total loss values mentioned in Table 3.

6.8.1.3 For transformers having voltage class above 22 kV and up to and including 33 kV, the permissible total loss values shall not exceed by 7 ½ percent of the maximum total loss values mentioned in Table 3.

NOTE — Maximum total losses at 85 °C are under consideration.

6.8.2 *Impedance*

The recommended impedance at 75 °C for different ratings is as per Table 3.

6.9 Permissible Flux Density and Over Fluxing

6.9.1 The maximum flux density in any part of the core and yoke at rated voltage and frequency shall be such that the flux density with +12.5 percent combined voltage and frequency variation from rated voltage and frequency shall not exceed 1.9 Tesla.

NOTE — The design calculations in support of flux density shall be furnished by manufacturer.

6.9.2 No load current up to 200 kVA shall not exceed 3 percent of full load current and will be measured by energizing the transformer at rated voltage and frequency. Increase of 12.5 percent of rated voltage shall not increase the no load current by 6 percent maximum of full load current.

Table 3 Maximum Total Losses Upto 11 kV Class Transformers

(*Clauses* 6.8.1.1, 6.8.1.2, 6.8.1.3 *and* 6.8.2)

Sl No.	Rating (kVA)	Impedance (Percent)	Maximum Total Loss (W)									
			Energy Efficiency Level 1		Energy Efficiency Level 2		Energy Efficiency Level 3		Energy Efficiency Level 4		Energy Efficiency Level 5	
			50 Percent Load	100 Percent Load	50 Percent Load	100 Percent Load	50 Percent Load	100 Percent Load	50 Percent Load	100 Percent Load	50 Percent Load	100 Percent Load
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)
i)	16	4.5	135	440	120	400	108	364	97	331	87	301
ii)	25	4.5	190	635	175	595	158	541	142	493	128	448
iii)	63	4.5	340	1140	300	1050	270	956	243	870	219	791
iv)	100	4.5	475	1650	435	1500	392	1365	352	1242	317	1130
v)	160	4.5	670	1950	570	1700	513	1547	462	1408	416	1281
vi)	200	4.5	780	2300	670	2100	603	1911	543	1739	488	1582

NOTE — For non-preferred ratings of Table 1, maximum losses are subject to agreement between the user and the supplier.

6.10 Limits of Temperature-rise

6.10.1 The type of cooling shall be type KNAN as per IS 2026 (Part 2).

6.10.2 The following types of dielectric systems are considered:

a) Type ‘A’ — Conventional kraft paper insulation on winding conductors and all other insulating materials of conventional type (e.g. radial/axial spacers, cylinders and barriers, static end ring if any, moulded angle ring/cap if any, shall be of conventional pressboard) immersed in ester liquid.

b) Type ‘B’ — Thermally Upgraded Paper (TUP) [*see* IS 2026 (Part 7) and IS 2026 (Part 14)] or class 130 °C/140 °C paper on winding conductors or enamel coating of minimum 130 °C class and all other insulating materials of conventional type, immersed in ester liquid.

6.10.3 The permissible temperature-rise shall not exceed the limits as given below:

Dielectric System	Top Liquid temperature rise	Average Winding temperature rise
(1)	(2)	(3)
Type A	40 °C	45 °C
Type B	50 °C	55 °C

7 TECHNICAL PARAMETERS OF THREE PHASE DISTRIBUTION TRANSFORMERS HIGHER THAN 200 KVA UP TO AND INCLUDING 2 500 KVA (NON-SEALED AND SEALED TYPE)

7.1 Ratings

The standard ratings shall be as per Table 4.

Table 4 Standard Ratings

(*Clause* 7.1)

Sl No.	Nominal System Voltage	Standard Ratings (kVA)
(1)	(2)	(3)
i)	Up to and including 11 kV	250, 315, 400, 500, 630, 800, 1 000, 1 250, 1 600, 2 000 and 2 500
ii)	Above 11 kV up to and including 22 kV	250, 315, 400, 500, 630, 800, 1 000, 1 250, 1 600, 2 000 and 2 500
iii)	Above 22 kV up to and including 33 kV	250, 315, 400, 500, 630, 800, 1 000, 1 250, 1 600, 2 000 and 2 500

7.2 Rated Frequency

The rated frequency shall be 50 Hz.

7.3 Nominal System Voltage

Nominal system voltage shall be chosen from the following:

HV — 3.3, 6.6, 11, 22 and 33 kV

LV — 415 V

7.4 Basic Insulation Level (BIL)

The minimum basic insulation level (BIL) shall be as given in Table 5.

Table 5 Minimum Basic Insulation Level

(*Clause* 7.4)

Sl No.	Nominal System Voltage (kV)	Minimum Basic Insulation Level (kV_p)
(1)	(2)	(3)
i)	3.3	40
ii)	6.6	60
iii)	11	75
iv)	22	125
v)	33	170

NOTE — Insulation coordination of all relevant fittings and accessories corresponding to higher BIL values shall be ensured.

7.5 No-Load Voltage Ratios

The no-load voltage ratios shall be as follows:

3 300/433-250, 6 600/433-250, 11 000/433-250, 22 000/433-250 and 33 000/433-250 V

NOTE — Secondary voltage may be selected as 415-240 V, subject to agreement between user and supplier.

7.6 Winding Connections and Phase Displacement

The primary winding shall be connected in delta and the secondary winding in star [vector symbol, Dyn 11 (*see* IS 2026 Part 1)], so as to produce, a positive phase displacement of 30° from the primary to the secondary vectors of the same phase. The neutral of the secondary winding shall be brought out to a separate insulated terminal.

Alternatively [Dyn1 (*see* IS 2026 Part 1)] can also be specified. If system and application requirements demand different vector groups, the same can also be adopted.

7.7 Tapping Ranges and Tapping Methods

7.7.1 The standard tapping ranges, when taps are provided, shall be as follows:

Winding tapped	—	HV
Number of tap positions	—	7
Voltage variations	—	+5 percent to −10 percent in steps of 2.5 percent for variation of HV

7.7.2 Off circuit tap-changing arrangement shall be either by means of links or by means of an externally-operated switch with mechanical locking device and a position indicator. Arrangement for pad-locking shall be provided.

7.7.3 For ratings 500 kVA and above, on load tap changers may be provided for variation of HV voltage from + 5 percent to – 15 percent in steps of 2.5 percent.

NOTE — Wherever the requirement of OLTC is envisaged, OLTC with a proven design and testing should be used in order to ensure the suitability and prevention of liquid exposure to the atmosphere.

7.7.4 Provision of any other tapping range and tapping step is subject to agreement between user and the supplier.

7.8 Losses and Impedance Values

7.8.1 *Losses — Multiple rating with regard to Energy Efficiency*

7.8.1.1 For transformers of HV voltage up to 11 kV, the total losses (no-load + load losses at 75 °C) at 50 percent of rated load and total losses at 100 percent of rated load shall not exceed the maximum total loss values given in Table 6.

7.8.1.2 For transformers having voltage class above 11 kV and up to and including 22 kV, the permissible total loss values shall not exceed by 5 percent of the maximum total loss values mentioned in Table 6.

7.8.1.3 For transformers having voltage class above 22 kV and up to and including 33 kV, the permissible total loss values shall not exceed by 7 ½ percent of the maximum total loss values mentioned in Table 6.

NOTE — Maximum total losses at 85 °C are under consideration.

7.8.2 *Impedance*

The recommended percent impedance at 75 °C for different ratings is as per Table 6.

Table 6 Maximum Total Losses up to 11 kV Class Transformer

(*Clauses* 7.8.1.1, 7.8.1.2, 7.8.1.3 *and* 7.8.2)

Sl No.	Rating (kVA)	Impedance (Percent)	Maximum Total Loss (W)									
			Energy Efficiency Level 1		Energy Efficiency Level 2		Energy Efficiency Level 3		Energy Efficiency Level 4		Energy Efficiency Level 5	
			50 Percent Load	100 Percent Load	50 Percent Load	100 Percent Load	50 Percent Load	100 Percent Load	50 Percent Load	100 Percent Load	50 Percent Load	100 Percent Load
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)
i)	250	4.50	980	2 930	920	2 700	864	2 488	811	2 293	761	2 113
ii)	315	4.50	1 025	3 100	955	2 750	890	2 440	829	2 164	772	1 920
iii)	400	4.50	1 225	3 450	1 150	3 330	1 080	3 214	1 013	3 102	951	2 994
iv)	500	4.50	1 510	4 300	1 430	4 100	1 354	3 909	1 282	3 727	1 215	3 554
v)	630	4.50	1 860	5 300	1 745	4 850	1 637	4 438	1 536	4 061	1 441	3 717
vi)	800	5.00	2 287	6 403	2 147	5 838	2 015	5 323	1 892	4 853	1 776	4 425
vii)	1 000	5.00	2 790	7 700	2 620	7 000	2 460	6 364	2 310	5 785	2 170	5 259
viii)	1 250	5.00	3 300	9 200	3 220	8 400	3 142	7 670	3 066	7 003	2 991	6 394
ix)	1 600	6.25	4 200	11 800	3 970	11 300	3 753	10 821	3 547	10 363	3 353	9 924
x)	2 000	6.25	5 050	15 000	4 790	14 100	4543	13 254	4309	12 459	4 088	11 711
xi)	2 500	6.25	6 150	18 500	5 900	17 500	5660	16 554	5430	15 659	5 209	14 813

7.9 Permissible Flux Density and Overfluxing

7.9.1 The maximum flux density in any part of the core and yoke at rated voltage and frequency shall be such that the flux density with + 12.5 percent combined voltage and frequency variation from rated voltage and frequency does not exceed 1.9 Tesla.

NOTE — The design calculations in support of flux density shall be furnished by the manufacturer.

7.9.2 No load current shall not exceed 2 percent of the full load current and shall be measured by energizing the transformer at rated voltage and frequency. Increase of 12.5 percent of rated voltage shall not increase the no load current by 5 percent of full load current.

7.10 Limits of Temperature Rise

7.10.1 The type of cooling shall be KNAN as per IS 2026 (Part 2).

7.10.2 The following types of dielectric systems are considered:

a) Type A (*see* **6.10.2**); and
b) Type B (*see* **6.10.2**).

7.10.3 The permissible temperature-rise shall not exceed the limits as given below:

Dielectric System	Top Liquid Temperature Rise	Average Winding Temperature Rise
(1)	(2)	(3)
TYPE A	45 °C	50 °C
TYPE B	55 °C	60 °C

8 TECHNICAL PARAMETERS OF SINGLE PHASE DISTRIBUTION TRANSFORMERS UP TO AND INCLUDING 100 KVA (SEALED TYPE)

8.1 Ratings

The standard ratings shall be as per Table 7.

Table 7 Standard Ratings

(*Clause* 8.1)

Sl No.	Nominal System Voltage	Standard Ratings (kVA)
(1)	(2)	(3)
i)	Up to and including 11 kV	5, 10, 16, 25, *50, *75 and *100
ii)	Above 11 kV up to and including 22 kV	5, 10, 16, 25, *50, *75 and *100
iii)	Above 22 kV up to and including 33 kV	5, 10, 16, 25, *50, *75 and *100

*ratings are non-preferred.

8.2 Rated Frequency

The rated frequency shall be 50 Hz.

8.3 Nominal System Voltage

Nominal system voltage shall be chosen from the following:

HV — 3.3, 6.6, 11, 22 and 33 kV

LV — 415 V (240 V, 1 phase)

8.4 Basic Insulation Level (BIL)

Minimum basic insulation level shall be as given in Table 8.

Table 8 Minimum Basic Insulation Level

(*Clause* 8.4)

Sl No.	Nominal System Voltage (kV)	Minimum BIL (kVp)
(1)	(2)	(3)
i)	3.3	40
ii)	6.6	60
iii)	11	75
iv)	22	125
v)	33	170

NOTE — Insulation coordination of all relevant fittings and accessories corresponding to higher BIL values shall be ensured.

8.5 No Load Voltage Ratio

The no-load voltage ratios shall be as follows:	
3 300/√3/250 V,	3 300/250 V
6 600/√3/250 V,	6 600/250 V
11 000/√3/250 V,	11 000/250 V
22 000/√3/250 V,	22 000/250 V
33 000/√3/250 V,	33 000/250 V

NOTE — Secondary voltage may be selected as 415-240 V, subject to agreement between the user and the supplier.

8.6 Number of Phases and Polarity

Number of phases shall be one (single phase).

Polarity: Additive or subtractive

8.7 Tap Changing Arrangement

Taps are not required.

8.8 Losses and Impedance Values

8.8.1 *Losses — Multiple Rating with Regard to Energy Efficiency*

8.8.1.1 For transformer of HV voltage up to 11 kV, the total losses (no load + load losses at 75 °C) at 50 percent of rated load and total losses at 100 percent of rated load shall not exceed the maximum total loss values given in Table 9.

8.8.1.2 For transformers having voltage class above 11 kV and up to and including 22 kV, the permissible total loss values shall not exceed by 7 ½ percent of the maximum total loss values mentioned in Table 9.

8.8.1.3 For transformers having voltage class above 22 kV and up to and including 33 kV, the permissible total loss values shall not exceed by 10 percent of the maximum total loss values mentioned in Table 9.

NOTE — Maximum total losses at 85 °C are under consideration.

8.8.2 *Impedance*

The recommended percent impedance at 75 °C for different ratings is as per Table 9.

8.9 Permissible Flux Density and Overfluxing

8.9.1 The maximum flux density in any part of the core and yoke at rated voltage and frequency shall be such that the flux density with + 12.5 percent combined voltage and frequency variation from rated voltage and frequency does not exceed 1.9 Tesla.

NOTE — The design calculations in support of flux density shall be furnished by the manufacturer.

8.9.2 No load current shall not exceed 3 percent of full load current and will be measured by energizing the transformer at rated voltage and frequency. Increase of 12.5 percent of rated voltage shall not increase the no-load current by 6 percent maximum of full load current.

Table 9 Maximum Total Losses of Single Phase Transformers Up to 11 kV

(*Clauses* 8.8.1.1, 8.8.1.2, 8.8.1.3 *and* 8.8.2)

Sl No.	Rating (kVA)	Impedance (Percent)	Maximum Total Loss (W)									
			Energy Efficiency Level 1		Energy Efficiency Level 2		Energy Efficiency Level 3		Energy Efficiency Level 4		Energy Efficiency Level 5	
			50 Percent Load	100 Percent Load	50 Percent Load	100 Percent Load	50 Percent Load	100 Percent Load	50 Percent Load	100 Percent Load	50 Percent Load	100 Percent Load
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)
i)	5	2.50	35	95	30	75	27	68	24	62	21	57
ii)	10	4.00	60	170	55	150	50	135	45	122	40	112
iii)	16	4.00	82	224	63	190	58	175	54	164	50	145
iv)	25	4.00	110	300	95	260	88	240	80	225	74	210
v)	50	4.00	210	590	190	520	177	480	160	451	148	420
vi)	75	4.00	310	880	285	780	265	720	242	670	223	625
vii)	100	4.00	410	1 140	375	1 030	350	964	320	900	299	842

8.10 Limits of Temperature Rise

8.10.1 The type of cooling shall be KNAN as per IS 2026 (Part 2).

8.10.2 The following types of dielectric systems are considered:

a) Type A (*see* **6.10.2**)

b) Type B (*see* **6.10.2**)

8.10.3 The permissible temperature-rise shall not exceed the limits as given below:

Dielectric System	Top Liquid Temperature Rise	Average Winding Temperature Rise
(1)	(2)	(3)
TYPE A	40 °C	45 °C
TYPE B	50 °C	55 °C

9 STANDARD MATERIALS

9.1 Major material used in the transformer shall conform to the following Indian Standards:

a) Cold rolled grain oriented electrical steel — IS 3024;

b) Amorphous core material — IS 16585;

c) Copper/aluminium conductor — IS 191, IS 1897, IS 7404, IS 12444, IS 13730/IS 6162 series as given in Annex A;

d) Kraft paper — IS 9335 series as given in Annex A;

e) Press board — IS 1576;

f) Synthetic organic ester — IS 16081; and

g) Natural ester — IS 16659.

10 TERMINAL ARRANGEMENT

10.1 For Three Phase Transformers

10.1.1 The transformers shall be fitted on high voltage and low voltage sides with outdoor type bushings of appropriate voltage and current ratings. The high voltage bushings (3 Nos.) shall conform to IS/IEC 60137. The low voltage bushings (4 Nos.) shall conform to IS 7421. Alternatively, the low voltage side may be made suitable for adoption of PVC/XLPE cables of suitable size.

10.1.2 If required by the user, a suitable cable-end box may be provided on the high voltage and/or low voltage side. Alternatively bus duct arrangement may be provided on low voltage side by agreement between the user and the supplier.

NOTE — Porcelain/epoxy/silicon rubber bushing may also be used in the cable box subject to agreement between the user and the supplier.

10.1.3 In case of sealed type transformer, the terminal arrangements shall be such that it shall be possible to replace the bushings (external) without opening the cover and also without affecting the sealing of the transformer.

The bushing shall conform to relevant Part/Section of IS 3347 depending on the voltage class.

NOTE — Any other suitable arrangement can be used subject to agreement between the user and the supplier.

10.1.4 Gaskets shall be made of synthetic rubber or synthetic rubberized cork resistant to hot transformer ester liquid.

10.1.5 The dimensions of bushings of the following voltage classes shall conform to the following Indian Standards mentioned against them:

Voltage Class	*For Porcelain Parts*	*For Metal Parts*
(1)	(2)	(3)
Up to 1.0 kV bushings	IS 3347 (Part 1/Sec 1)	IS 3347 (Part 1/Sec2)
3.6 kV bushings	IS 3347 (Part 2/Sec 1)	IS 347 (Part 2/Sec 2)
12 kV bushings	IS 3347 (Part 3/Sec 1)	IS 3347 (Part 3/Sec 2)
24 kV bushings	IS 3347 (Part 4/Sec 1)	IS 3347 (Part 4/sec 2)
36 kV bushings	IS 3347 (Part 5/Sec 1)	IS 3347 (Part 5/Sec 2)
52 kV bushings	IS 3347 (Part 8/Sec 1)	IS 3347 (Part 8/Sec 2)

NOTES

1 For heavily polluted atmosphere, dimensions of bushings shall conform to IS 8603 or IS 8603 (Part 4) depending on the voltage class.

2 Cast resin or polymer bushing can also be used with performance requirements as per IS/IEC 60137 and IS 7421.

3 Epoxy bushings can also be used with performance requirements as per agreement between the user and the supplier.

10.2 For Single Phase Transformers

For 3.3/√3, 6.6/√3, 11/√3, 22/√3, and 33/√3 kV transformers, neutral end of the HV winding shall be brought out to neutral through 1.0 kV bushing. Neutral terminal shall be connected to tank by a tinned copper strip of adequate size.

For 3.3, 6.6, 11, 22, 33 kV transformers, two HV bushings shall be used for termination of both ends of HV winding.

The HV bushings shall be fixed to the top cover or side walls and the LV bushings of 1.0 kV class shall be fixed to the transformer tank on sides or on the top cover.

10.3 Marking and Relative Positions of Terminals

Appropriate characters in accordance with IS 2026 (Part 1) shall be indelibly marked upon or adjacent to terminals.

11 MINIMUM CLEARANCES IN AIR

The minimum phase-to-phase and phase-to-earth external clearances for LV and HV bushings shall be as per Table 10.

Table 10 External (Air) Clearances between Bushings Mounted on Transformers

(*Clause* 11)

Nominal System Voltage	Phase to Phase clearance (mm)	Phase to earth clearance (mm)
(1)	(2)	(3)
Up to 1.1 kV	75	40
11 kV	255	140
22 kV	330	230
33 kV	350	320

11.1 For transformers with air filled cable-end box/connection chamber, the phase-to-phase and phase-to-earth clearance shall be as per Table 11.

Table 11 Air Clearances in Cable Box

(*Clause* 11.1)

Nominal System Voltage	Phase to Phase Clearance in mm	Phase to Earth Clearance in mm
(1)	(2)	(3)
Up to 1.1 kV	25	20
11 kV	130	80
22 kV	240	140
33 kV	350	220

12 CONNECTORS (APPLICABLE FOR BARE BUSHING TERMINATIONS ONLY)

Wherever specified, suitable bimetallic connectors (clamp type) shall be provided on both HV and LV side in order to ensure sound and robust connection.

13 MARKING

13.1 Rating Plate

Each transformer shall be provided with rating plate made of anodized aluminum/stainless steel material securely fixed on the outer body, easily accessible, showing the information given in Fig. 1 for 3 phase transformers and Fig. 2 for single phase transformers. The entries on the rating plate shall be indelibly marked for example, by etching, engraving or stamping.

13.2 Terminal Marking Plate

Each transformer shall be provided with a terminal marking plate in accordance with Fig. 3 to Fig. 5 whichever is applicable.

13.3 The rating and terminal marking plates may be combined into one plate at the option of the manufacturer.

NOTE — Dimensions of Rating Plate, Terminal Marking Plate and Combined Rating and Terminal Plate can be changed subject to agreement between the user and the supplier.

13.4 BIS Certification Marking

The distribution transformer conforming to the requirements of this standard may be certified as per the conformity assessment schemes under the provisions of the *Bureau of Indian Standards Act*, 2016 and the Rules and Regulations framed thereunder, and the distribution transformer may be marked with the Standard Mark.

14 MOUNTING ARRANGEMENT

14.1 The under-base of all three phase transformers upto 200 kVA ratings shall be provided with two channels of minimum size 75 mm × 40 mm as shown in Fig. 6 to make them suitable for fixing to a platform or plinth.

14.2 The under base of all transformers beyond 200 kVA may be as per Fig. 7 to make them suitable for mounting on rollers.

14.3 Suitable pole mounting arrangement may be alternatively provided for 3 phase transformers upto 500 kVA, subject to agreement between the user and the supplier.

14.4 Single phase transformers are pole mounted type and shall be provided with two mounting lugs suitable for fixing the transformer to a single pole by means of two bolts of 20 mm diameter.

Both mounting lugs are made with steel of minimum 5 mm thickness.

NOTE — For single phase transformers above 25 kVA, base channels may be provided as per agreement between the user and the supplier.

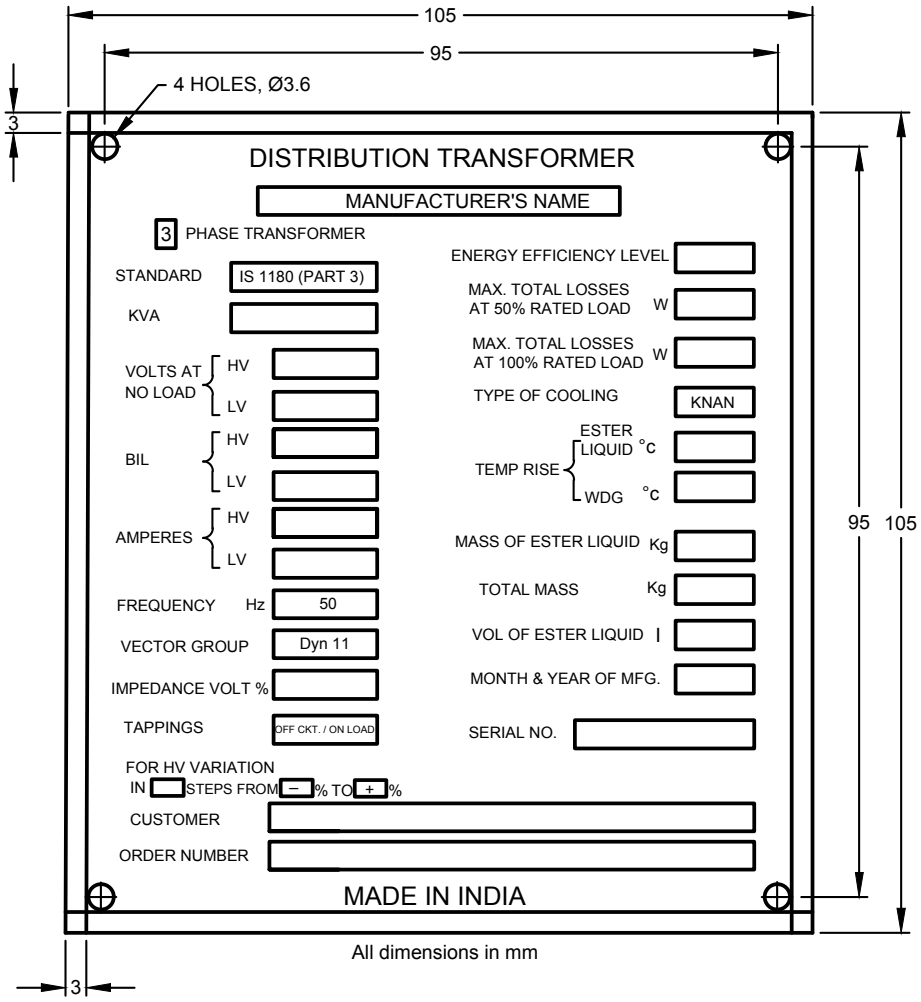


FIG. 1 RATING PLATE FOR 3 PHASE TRANSFORMERS

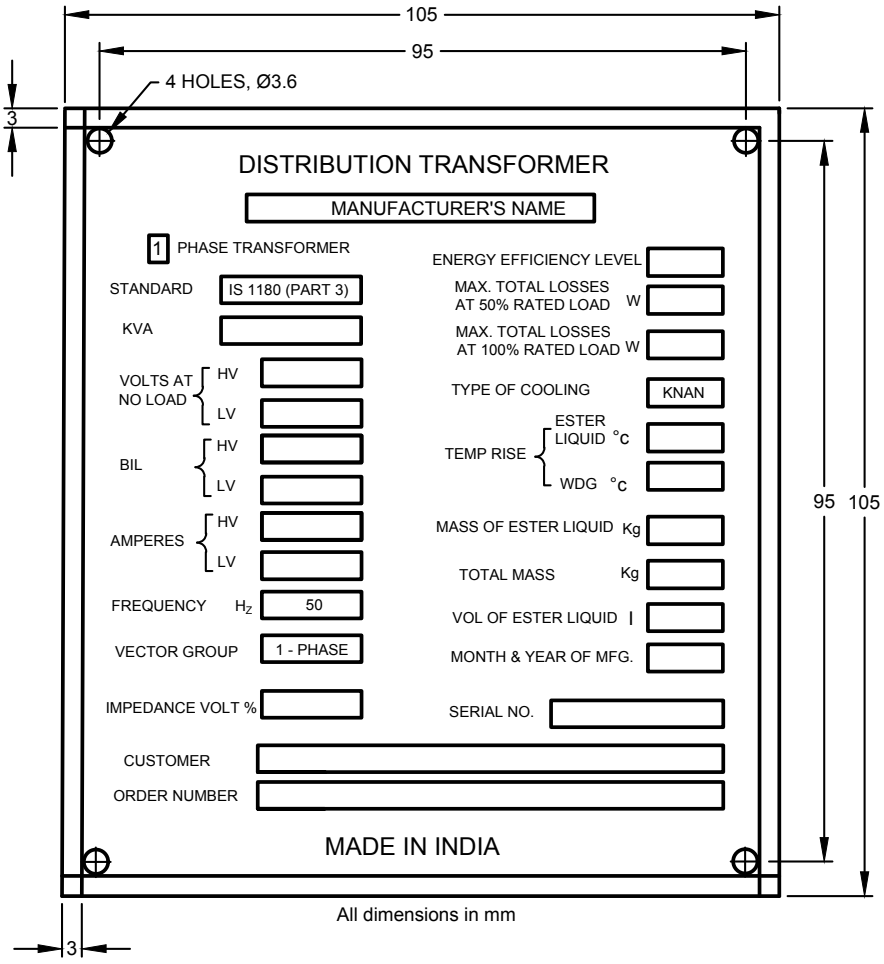
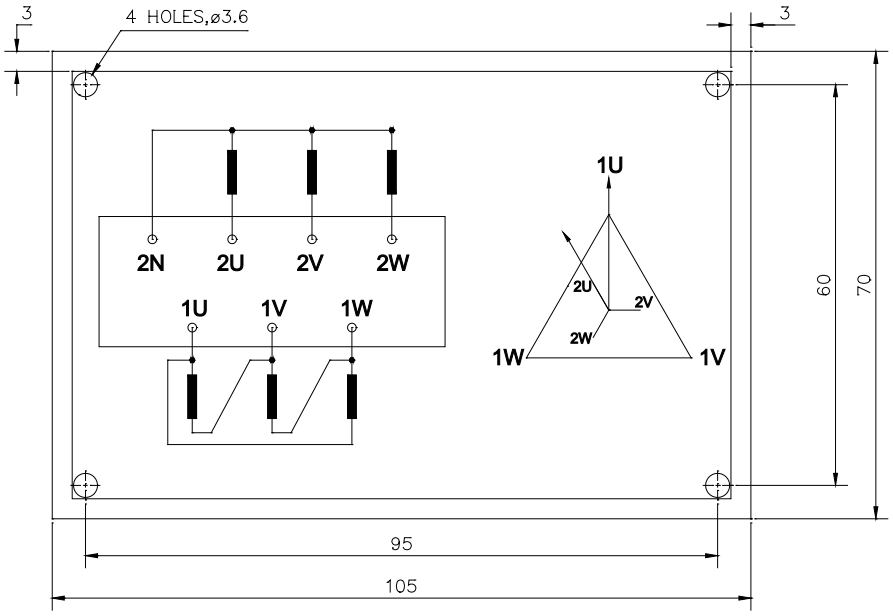
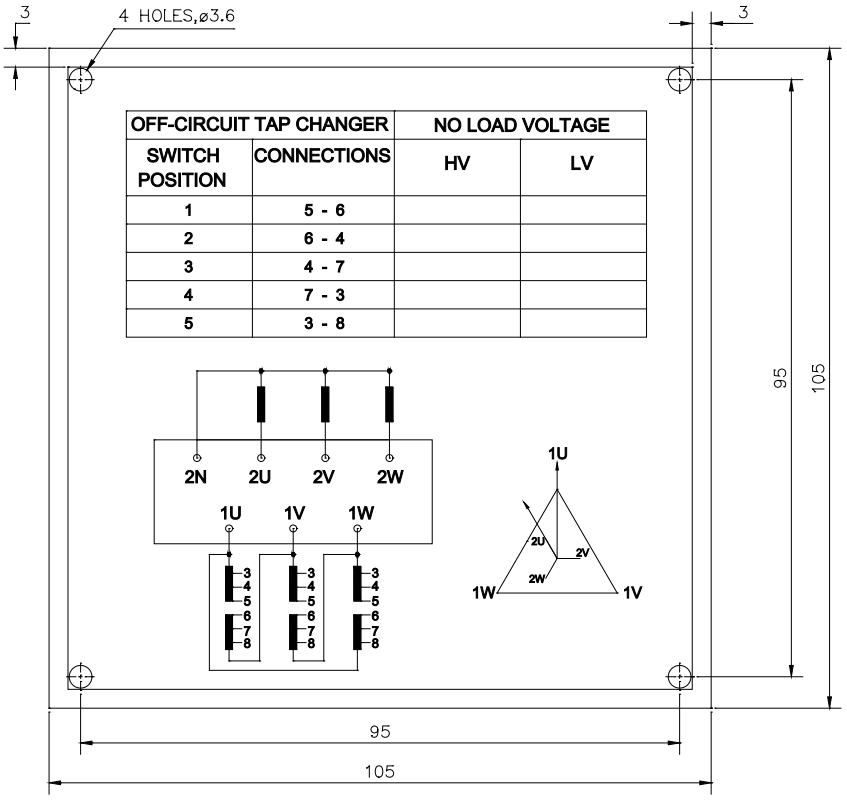


FIG.2 RATING PLATE FOR SINGLE PHASE TRANSFORMERS



All dimensions in mm

FIG. 3 TERMINAL MARKING PLATE FOR 3 PHASE TRANSFORMERS WITHOUT TAPS



All dimensions in mm

FIG. 4 TERMINAL MARKING PLATE FOR 3 PHASE TRANSFORMERS WITH TAPS

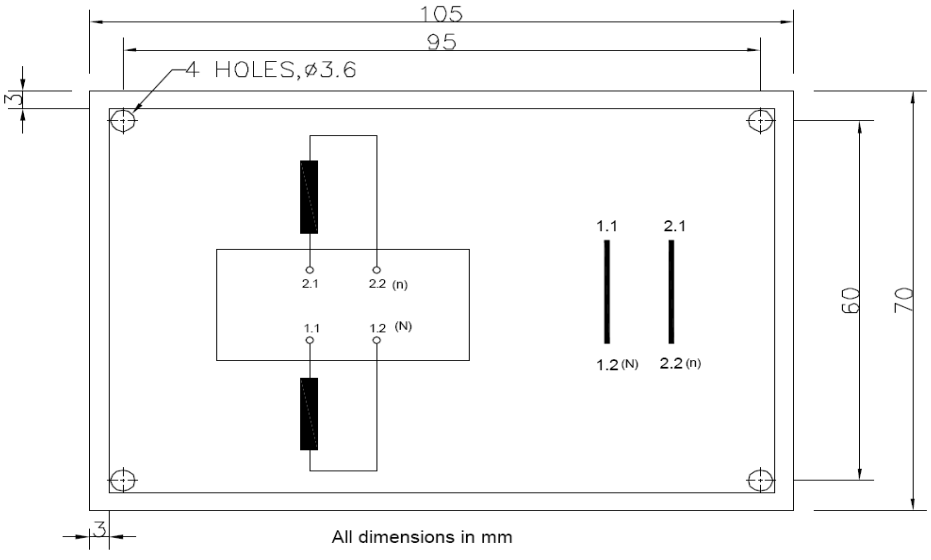
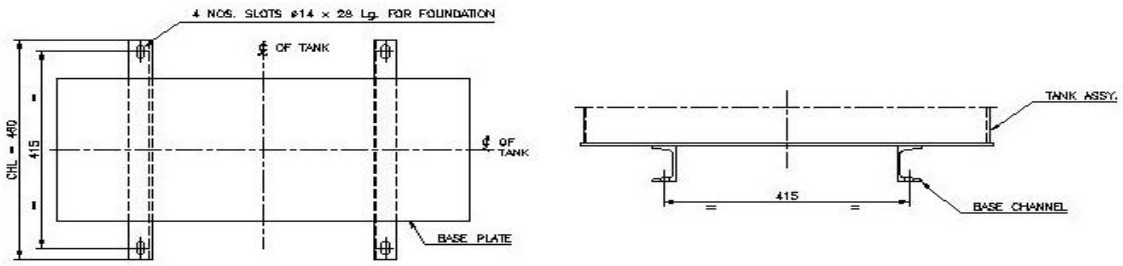


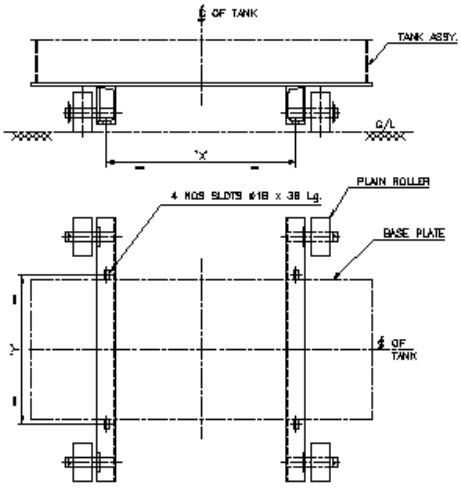
FIG. 5 TERMINAL MARKING PLATE FOR SINGLE PHASE TRANSFORMERS



All dimensions in mm

NOTE — Any other mounting dimensions are subject to agreement between the user and the supplier.

FIG. 6 MOUNTING DIMENSION OF TRANSFORMERS UP TO 200 KVA



Rating (kVA)	X	Y
2 500	1200	800
2 000	900	800
1 600	900	800
1 250	800	800
1 000	800	800
800	800	800
630	800	800
500	700	450
400	700	450
315	600	450
250	500	415

All dimensions in mm

NOTES

1 Bidirectional rollers can also be used as per mutual agreement between the user and the supplier.

2 Any other mounting dimensions are subjected to agreement between the user and the supplier.

FIG. 7 MOUNTING DIMENSIONS OF TRANSFORMERS BEYOND 200 KVA

14.5 For pad mounted transformers other constructional features and fixing details are subject to agreement between the user and the supplier.

15 TRANSFORMER TANK

15.1 Construction

15.1.1 For non-sealed or sealed type transformer, transformer tank can be of plain tank configuration with/without radiator fins or cooling tubes. The tank can also be made of corrugated panels of adequate thickness, also used for cooling. The transformer tank covers shall be bolted/clamped alternatively welded with tank rim so as to make a leak proof joint. The curb design in case of welded construction shall be such that it is possible to remove the weld and reweld the tank at least two times.

NOTE — Minimum thickness of corrugations shall be 1.0 mm.

15.1.2 The transformer tank shall be of adequate mechanical strength to withstand positive and negative pressures built up inside the tank while the transformer is in operation.

15.1.3 All welding operations shall be carried out by qualified welders.

15.1.4 The tank design shall be such that the core and windings can be lifted freely.

15.1.5 For round shape single phase sealed type transformers, the circular base plate edges of the tank shall be folded upward for at least 25 mm, to have sufficient overlap with vertical sidewall of the transformer.

15.2 Pressure and Vacuum Requirements

15.2.1 In case of transformers up to 200 kVA, the plain tank shall be capable of withstanding a pressure of 80 kPa and a vacuum of 250 mm of mercury. Limiting values of the deflections are specified in **21.5.1.**

For transformers above 200 kVA, the plain tank shall be capable of withstanding a pressure of 80 kPa and a vacuum of 500 mm of mercury. Limiting values of the deflections are specified in **21.5.2.**

For single phase transformers up to and including 100 kVA, the plain tank shall be capable of withstanding a pressure of 100 kPa and a vacuum of 760 mm of mercury. Limiting values of deflections are specified in **21.5.3.1.**

NOTE — Permanent deflection is not applicable for round tanks.

15.2.2 For three phase transformers up to 2 500 kVA, transformer tanks with corrugations shall be designed for a pressure of 15 kPa measured at the top of the tank with no leakage.

For single phase transformers up to 100 kVA, transformer tanks with corrugations shall be designed for a pressure of 15 kPa measured at the top of the tank with no leakage.

15.2.3 For three phase sealed type transformers with cover welded to the curb of the tank shall be of sound and robust construction so as to withstand pressure of 80 kPa without any deformation.

15.2.4 For single phase transformers of sealed type construction, when the space on the top liquid is filled with dry air or inert gas, the inert gas plus liquid volume inside the tank shall be such that even under extreme operating conditions, the pressure generated inside the tank does not exceed 0.4 kg/cm^2 positive or negative.

15.3 All bolts/nuts/washers exposed to atmosphere shall be as follows:

a) Size 12 mm or below — stainless steel.
b) Above 12 mm — steel with suitable finish like electro galvanized with passivation or hot dip galvanized.

15.4 Gaskets wherever used shall conform to Type III as per IS 11149/Type C as per IS 4253 (Part 2) and shall be compatible with high contact temperature i.e. thermal class of 130 °C.

15.5 Inside of tank shall be painted with varnish or liquid resistant paint. For external surfaces one coat of thermo setting powder paint or one coat of epoxy primer followed by two coats of polyurethane base paint shall be used. Table 12 shall be referred to for paint thickness for normal to medium corrosive atmosphere. For highly polluted atmosphere and special application external paint work shall be subject to agreement between the user and the transformer manufacturer.

Table 12 Paint scheme for Distribution Transformers

(*Clause* 15.5)

Sl No.	Paint Type	Area to be Painted	No. of Coats	Total Dry Film Thickness Min. (microns)
(1)	(2)	(3)	(4)	(5)
i)	Thermo setting powder paint	Inside	01	30
		Outside	01	60
ii)	Liquid Paint			
	a) Epoxy (primer)	Outside	01	30
	b) Polyurethane (Finish coat)	Outside	02	25 each
	c) Hot liquid resistant paint/Varnish	Inside	01	35/10

NOTE — It is recommended to choose paint shade of the transformer as green 218 following IS 5.

16 CONSERVATOR FOR NON-SEALED TYPE TRANSFORMERS

16.1 Transformers of ratings 63 kVA and above with plain tank construction, the provision of conservator is mandatory. For sealed type transformers with or without inert gas cushion, conservator is not required.

16.2 When a conservator is provided, liquid gauge and the plain or de-hydrating breathing device shall be fixed to the conservator which shall also be provided with a drain plug and a filling hole (1¼" normal size thread) with cover. The capacity of a conservator tank shall be designed keeping in view the total quantity of liquid and its contraction and expansion due to temperature variations. In addition, the cover of main tank shall be provided with an air release plug to enable air trapped within to be released,unless the conservator is so located as to eliminate the possibility of air being trapped within the main tank.

In case of transformers immersed in natural ester liquid, care shall be taken to prevent the liquid getting exposed to atmosphere by the use of an airbag (which is connected to a breather with silica gel) or suitable liquid preservation system.

16.3 The inside diameter of the pipe connecting the conservator to the main tank should be 25 to 50 mm and it should be projected into the conservator so that its end

is at least 20 mm above the bottom of the conservator so as to create a sump for collection of impurities. The minimum ester liquid level corresponding to −5 °C should be above the sump level.

17 ABILITY OF TRANSFORMERS TO WITHSTAND EXTERNAL SHORT CIRCUIT

The performance of transformer under external short-circuit conditions shall be in accordance with IS 2026 (Part 5).

18 EFFICIENCY AND REGULATION

When statements of efficiency and regulations are required they shall be based on specified loading at the rated kVA and unity power factor and computed in accordance with Annex C and Annex D respectively.

NOTE — Efficiency and regulations at other power factors as agreed between the user and supplier shall also be computed.

19 TOLERANCES

The tolerance on electrical performance excluding losses shall be as given in IS 2026 (Part 1).

20 FITTINGS

20.1 Standard Fittings

The following standard fittings shall be provided:

a) Two earthing terminals with the earthing symbol ⏚;

b) Liquid level gauge indicating level at minimum, 30 °C and maximum operating temperature.

NOTES

1 Minimum and maximum positions correspond to the operating temperature of −5 °C and 105 °C respectively (for non-sealed type transformer).

2 Only minimum position corresponding to the operating temperature of 30 °C (for sealed type transformers).

c) Air release device (for non-sealed type transformers, where natural esters are not used);

d) Rating and terminal marking plates;

e) Dehydrating breather (connecting the air bags if present) shall be provided for non-sealed type transformers.

f) Drain-*cum*-sampling valve preferably steel with plug for three phase transformers (for transformers above 500 kVA);

NOTE— Valve size shall be as per agreement between the user and the supplier.

g) Thermometer pocket with cap;

h) Ester liquid/Nitrogen/Air filling hole having (1¼" nominal size thread) with cover (for sealed type transformers without conservator);

j) Lifting lugs for the complete transformer as well as for core and winding assembly;

k) Pressure relief device or explosion vent [for sealed type transformers (for all ratings) and non-sealed type transformers (for ratings above 200 kVA)];

m) One filter valve on the upper side of the tank (for transformers above 200 kVA);

n) HV side neutral grounding strip (where one of the HV bushing terminal is connected to earth);

p) LV earthing arrangement for single phase transformers;

q) Buchholz relay for transformers above 1 000 kVA; *and*

r) Arcing horns for HT side (one number per phase)

NOTES

1 For cable box/bus duct arrangement, arcing horns are not required.

2 Providing arcing horn is optional in case lightning arrester is provided.

20.2 Optional Fittings

The following shall be available as additional fittings at the option of the user wherever specified:

a) Dehydrating breather in lieu of plain breathing device for transformers up to 200 kVA;

b) Filter valve for transformers up to 200 kVA;

NOTE — Valve size shall be as per agreement between the user and the supplier.

c) Suitable rating lightning arrestors for HT side (one number per phase);

d) Bird guard;

e) Terminal connectors;

f) Liquid temperature indicator and winding temperature indicators for transformers above 200 kVA;

g) Jacking pads (for transformer above 1 600 kVA);

h) Buchholz relay (for transformers above 200 kVA);

j) Magnetic ester liquid level gauge (for transformer above 1 600 kVA) with low liquid level alarm contact;

k) Non return valve (for conducting pressure test);

m) Pressure relief device or explosion vent (up to 200 kVA for non-sealed type transformers);

n) Protection relay for sealed type transformers for internal parameters that is pressure, temperature, liquid level and gas detection;

p) 4 No's Anti-Theft stainless steel Fasteners with breakaway nut shall be provided at top cover (up to 200 kVA);

NOTE — IS 3639 describes some of the fittings and accessories.

q) Unidirectional flat rollers (for transformers above 200 kVA); and

r) Drain-cum-sampling valve preferably steel with plug for three phase transformers (for transformers up to 500 kVA).

NOTE— Valve size shall be as per agreement between the user and the supplier.

21 TESTS

21.1 General

All routine, type and special tests as described in **21.2** to **21.4** shall be performed as per relevant parts of IS 2026. Pressure and ester liquid leakage test shall be conducted as per **21.5**.

21.2 Routine Tests (to be conducted on all units)

The following shall constitute the routine tests:

a) Measurement of winding resistance [IS 2026 (Part 1)].

b) Measurement of voltage ratio and check of phase displacement [IS 2026 (Part 1)].

c) Measurement of short-circuit impedance (principal tapping, when applicable) and load loss at 50 percent and 100 percent load [IS 2026 (Part 1)].

d) Measurement of no-load loss and current [IS 2026 (Part 1)].

e) Measurement of insulation resistance [IS 2026 (Part 1)].

f) Induced over-voltage withstand test [IS 2026 (Part 3)].

g) Separate-source voltage withstand test [IS 2026 (Part 3)].

NOTE — For single phase transformer with 3.3/√3, 6.6/√3, 11/√3 or 22/√3 or 33/√3 kV and with 1.0 kV neutral bushing, this test shall be conducted at test voltage of neutral (3 kV rms for 1 min).

h) Pressure test (*see* **21.5**).

j) Ester liquid leakage test (*see* **21.5**).

21.3 Type Tests (to be conducted on one unit)

The following shall constitute the type tests:

a) Lightning impulse test [IS 2026 (Part 3)].

b) Temperature-rise test [IS 2026 (Part 2)].

NOTES

1 For Type A dielectric system, maximum total losses at 75 °C (as given in **6.8.1, 7.8.1** *and* **8.8.1**) shall be fed.

2 For Type B dielectric system, maximum total losses at 85 °C (measured during routine test and corrected to 85 °C) shall be fed.

c) Short-circuit withstand test [IS 2026 (Part 5)] (up to 200 kVA) *and*

NOTE — Routine tests before and after short circuit test shall be conducted as per IS 2026 (Part 1).

d) Pressure test (*see* **21.5**).

21.4 Special Tests (to be conducted on one unit)

The following constitutes the special tests which may be carried out subject to mutual agreement between the user and the supplier:

a) Determination of sound levels [IS 2026 (Part 10)];

b) Short-circuit withstand test [IS 2026 (Part 5)] (above 200 kVA);

NOTE — Routine tests before and after short circuit test shall be conducted as per IS 2026 (Part 1).

c) No load current at 112.5 percent voltage (*see* **6.9.2**, **7.9.2**, **8.9.2**);

d) *Paint adhesion test* — The test is performed as per ASTM D3359 (Standard Test Methods for measuring adhesion by tape test).

e) BDV and Moisture content of liquid in the transformer (IS 16081, IS 16099, IS 16899 or IS 16659, whichever is applicable).

NOTE — Tests at d) and e) may be carried out on more than one unit subject to agreement between user and supplier.

21.5 Pressure and Ester Liquid Leakage Test

21.5.1 *For Transformers up to 200 kVA*

21.5.1.1 *Pressure test (type test)*

For non-sealed and sealed type transformers, the transformer tank shall be subjected to air pressure of 80 kPa for 30 min (25 kPa for 30 min for corrugated tanks) and vacuum of 250 mm of mercury for 30 min. There should not be air leakage at any point.

The permanent deflection of flat plates, after pressure/vacuum has been released, shall not exceed the values given below.

Length of Plate	*Deflection*
Up to 750 mm	5.0 mm
751 to 1 250 mm	6.5 mm
1 251 to 1 750 mm	8.0 mm

NOTES

1 Permanent deflection is not applicable for corrugations.

2 Vaccum is not applicable for corrugations.

21.5.1.2 *Pressure (routine test)*

a) *Non-sealed type transformers (plain tanks)*

The transformer with bolted cover shall be tested at an air pressure of 35 kPa above atmosphere pressure maintained inside the tank for 10 min. There should be no leakage at any point.

b) *Corrugated tanks*

The corrugated transformer tank shall be tested for air pressure of 15 kPa above atmosphere pressure maintained inside the tank for 10 min. There should be no leakage at any point.

c) *Sealed type transformers*

The transformer with welded cover shall be tested at an air pressure of 80 kPa above atmosphere pressure maintained inside the tank for 10 min. There should be no leakage at any point.

21.5.1.3 *Ester liquid leakage test (routine test)*

The assembled transformer for non-sealed and sealed type with all fittings including bushings in position shall be tested at a pressure equivalent to twice the normal head measured at the base of the tank for 8 h. There should be no leakage at any point. Tank with corrugations shall be tested for ester liquid leakage test at a pressure of 15 kPa measured at the top of the tank for 6 h. There should be no leakage at any point.

21.5.2 *For Transformers Above 200 kVA and up to Including 2500 kVA.*

21.5.2.1 *Pressure test (type test)*

For non-sealed and sealed type transformers, the transformer tank shall be subjected to air pressure of 80 kPa for 30 min (25 kPa for 30 minutes for corrugated tanks) and vacuum of 500 mm of mercury for 30 min. There should not be air leakage at any point. The permanent deflection of flat plate, after pressure/vacuum has been released, shall not exceed the values given below.

Length of Plate	*Deflection*
Up to 750 mm	5.0 mm
751 mm to 1 250 mm	6.5 mm
1 251 mm to 1 750 mm	8.0 mm
Above 1 751 mm	9.0 mm

NOTES

1 Permanent deflection is not applicable for corrugations.

2 Vaccum is not applicable for corrugations.

21.5.2.2 *Pressure test (routine test)*

a) *Plain tanks*

The transformer tank with welded/bolted cover shall be tested at a pressure of 35 kPa above atmosphere pressure maintained inside the tank for 10 min. There should be no leakage at any point.

b) *Corrugated tanks*

The corrugated transformer tank shall be tested for air pressure of 15 kPa above atmosphere pressure maintained inside the tank for 10 min. There should be no leakage at any point.

21.5.2.3 *Ester liquid leakage test (routine test)*

The assembled transformer for non-sealed and sealed type with all fittings including bushing in position shall be tested at a pressure equivalent to twice the normal head measured at the base of the tank for 8 h. There should be no leakage at any point. Tank with corrugations shall be tested for Ester liquid leakage test at a pressure of 15 kPa measured at the top of the tank for 6 h. There should be no leakage at any point.

21.5.3 *For Single Phase Distribution Transformers up to Including 100 kVA.*

21.5.3.1 *Pressure test (type test)*

For transformers up to and including 100 kVA

The transformer tank shall be subjected to air pressure of 100 kPa for 30 min (15 kPa for 30 min for corrugated tanks) and vacuum of 760 mm of mercury for 30 min. There should be no air leakage at any point. The permanent deflection of flat plates, after pressure/vacuum has been released, shall not exceed the values given below:

Length of Plate	*Deflection*
Up to 750 mm	5 mm
751 mm to 1 250 mm	6.5 mm
1 251 mm to 1 750 mm	8.0 mm

NOTES

1 Permanent deflection is not applicable for round tanks.

2 Permanent deflection is not applicable for corrugations.

3 Vaccum is not applicable for corrugations.

21.5.3.2 *Pressure (routine test)*

For transformers up to and including 100 kVA

The transformer tank shall be tested at a pressure of 35 kPa for 10 min (15 kPa for 10 min for corrugated tanks). There should be no leakage at any point.

21.5.3.3 *Ester liquid leakage test (routine test)*

For transformers up to and including 100 kVA

The assembled transformer with all fittings including bushings in position, shall be tested at a pressure equivalent to twice the normal head measured at the base of the tank for 6 h. There should be no leakage at any point. Tank with corrugations shall be tested for ester liquid leakage test at a pressure of 15 kPa measured at the top of the tank for 6 h. There should be no leakage at any point.

22 INFORMATION REQUIRED WITH ENQUIRY AND ORDER

22.1 The information to be supplied by the manufacturer with enquiry and order to the purchaser shall be in accordance with Annex E.

ANNEX A

(*Clause* 2)

LIST OF REFERRED INDIAN STANDARDS

IS No.	*Title*
5 : 2007	Colours forready mixed paints andenamels (*sixth revision*)
191 : 2007	Copper — Specification (*fourth revision*)
554 : 1999	Pipe threads where pressure tight joints are required on the threads — Dimensions, tolerances and designation (*fourth revision*)
1576 : 1992	Solid pressboard for electrical purpose (*first revision*)
1608	Metallic materials — Tensile testing
(Part 1) : 2018	Method of test at room temperature (*fourth revision*)
(Part 3) : 2018	Method of test at low temperature
1747 : 1972	Nitrogen (*first revision*)
1885	Electrotechnical vocabulary
(Part 38) : 1993	Power transformers and reactors (*second revision*)
1897 : 2008	Copper strip for electrical purpose — Specification (*third revision*)
2026	Power transformers
(Part 1) : 2011	General (*second revision*)
(Part 2) : 2010	Temperature rise (*first revision*)
(Part 3) : 2018	Insulation levels, dielectric tests and external clearances in air (*fourth revision*)
(Part 5) : 2011	Ability to withstand short circuit (*first revision*)
(Part 7) : 2009	Loading guide for oil-immersed power transformers
(Part 8) : 2009	Application guide
(Part 10) : 2009	Determination of sound levels
(Part 14) : 2018	Liquid immersed power transformers using high-temperature insulation materials
3024 : 2015	Grain oriented electrical steel sheets and strip (*third revision*)
3347	Dimensions for porcelain transformer bushings for use in lightly polluted atmospheres
(Part 1/Sec 1) : 1979	Up to and including 1 kV, Section 1 Porcelain parts (*first revision*)
(Part 1/Sec 2) : 1979	Up to and including 1 kV – Section 2 Metal parts (*first revision*)
(Part 2/Sec 1) : 1979	3.6 kV bushings, Section 1 Porcelain parts (*first revision*)
(Part 2/Sec 2) : 1979	3.6 kV bushings, Section 2 Metal parts (*first revision*)
(Part 3/Sec 1) : 1988	17.5 kV bushings, Section 1 Porcelain parts (*second revision*)
(Part 3/Sec 2) : 1982	17.5 kV bushings, Section 2 Metal parts (*first revision*)
(Part 4/Sec 1) : 1988	24 kV bushings, Section1 Porcelain parts (*second revision*)
(Part 4/Sec 2) : 1982	24 kV bushings, Section 2 Metal parts (*first revision*)
(Part 5/Sec 1) : 1979	36 kV bushings, Section 1 Porcelain parts (*second revision*)
(Part 5/Sec 2) : 1979	36 kV bushings, Section 2 Metal parts (*first revision*)
(Part 8/Sec 1) : 1988	52 kV Bushings, Section 1 Porcelainparts
(Part 8/Sec 2) : 1992	52 kV bushings, Section 2 Metal parts
3639 : 1966	Fittings and accessories forpower transformers (*under revision*)
4253	Cork composition sheet:
(Part 2) : 2008	Cork and rubber (*second revision*)
6162	Paper-covered aluminum conductors
(Part 1) : 1971	Round conductors
(Part 2) : 1971	Rectangular conductors
7404	Paper covered copper conductors — Specification
(Part 1) : 1991	Round conductors (*first revision*)
7421 : 1988	Porcelain bushings for alternating voltages up to and including 1 000 V (*first revision*)

IS No.	*Title*
8603 : 2008	Dimensions for porcelain transformer bushings for use in heavily polluted atmospheres 12/17.5 kV, 24 kV and 36 kV (*first revision*)
8603 (Part 4) : 2003	Dimensions for porcelain transformer bushings for use in heavily polluted atmospheres: Part 4 52 kV Bushings
8999 : 2003	Gauging practice for pipe threads where pressure tight joints are required on the threads
9335	Cellulosic papers for electrical purposes
(Part1) : 1979	Definitions and general requirements
(Part 2) : 1998	Part 2 Methods of test (*first revision*)
(Part 3/Sec 1) : 1984	Specifications for individual materials, Section 1 General purposes electrical paper
(Part 3/Sec 3) : 1984	Specifications for individual materials, Section 3 Crepe paper
(Part 3/Sec 5) : 1985	Specifications for individual materials, Section 5 Special papers
11149 : 1984	Specification for rubber gaskets
12444 : 2020	Copper wire rods for electrical applications — Specification (*first revision*)
13730	Specification for particular types of winding wires:
(Part 0/Sec 1) : 2018	General requirements, Section 1 Enamelled round copper wire (*second revision*)
(Part 0/Sec 2) : 2018	General requirements, Section 2 Enamelled rectangular copper wire (*second revision*)
(Part 0/Sec 3) : 2012	General requirements, Section 3 Enameled round aluminum wire (*first revision*)
(Part 17) : 2014	Polyvinyl acetal enameled rectangular copper wire, Class 105 (*first revision*)
(Part 27) : 2018	Paper tape covered rectangular copper wire (*first revision*)
16081 : 2013	Insulating liquids — Specification for unused synthetic organic esters for electrical purposes
16659 : 2017	Fluids for electrotechnical applications — Unused natural esters for transformers and similar electrical equipment
13503 : 2013	Classification of insulating liquids (*first revision*)
16099 : 2013	Synthetic organic esters for electrical purposes — Guide for maintenance of transformer esters in equipment
IS 16899 : 2019	Guide for acceptance and maintenance of natural esterfluids in transformers
IS/IEC 60137 : 2017	Insulated bushings for alternative voltages above 1 000 volts

ANNEX B

(*Clause* 2)

LIST OF INTERNATIONAL STANDARDS

1. Cigre Brochure 443 (Working Group D1.32), DGA in Non-Mineral oil and Load Tap changers and improved DGA diagnosis criteria.
2. Cigre Brochure 436, WG A2.35, October 2010, Experiences in service with new insulating liquids.
3. ASTM D 6871-03, Standard specification for natural (vegetable oil) ester liquids in electrical apparatus.
4. IEEE/ANSI C57.12.22 - American National Standard for Pad-Mounted, Compartmental-Type, Self-Cooled, Three-Phase Distribution Transformers With High-Voltage Bushings, 2500 kVA and Smaller; High Voltage, 34 500 GrdY/19 920 Volts and Below; Low Voltage, 480 Volts and Below.
5. IEEE Std. C57.12.28, IEEE standard for Pad-mounted Equipment — Enclosure integrity.
6. IEEE Std. C57.12.29, IEEE standard for Pad — Mounted Equipment — Enclosure integrity for Coastal Environment.
7. IS 16785 : 2018/IEEE Std. C57.155 : 2014, IEEE guide for interpretation of gases generated in Natural Esters and Synthetic organic Esters immersed transformers.
8. IEC 62975 : 2021 — Natural esters — Guidelines for maintenance and use in electrical equipment.

ANNEX C

(*Clause* 18)

METHOD OF DECLARING EFFICIENCY

C-1 EFFICIENCY

C-1.1 The efficiency to be declared is the ratio of the output in kW to the input in kW and calculated as under.

$$\text{Efficiency } (\eta) = \frac{\text{Output}}{\text{Input}} = \frac{\text{Input} - \text{Total Losses}}{\text{Input}}$$

Total losses comprise:

a) No-load loss, which is considered to be constant at all loads; and

b) Load loss, which varies with load.

The total loss, on load is the sum of (a) and (b).

ANNEX D

(*Clause* 18)

CALCULATION OF INHERENT VOLTAGE REGULATION

D-1 INHERENT VOLTAGE REGULATION

D-1.1 The inherent voltage regulation from no-load to a load of any assumed value and power factor may be computed from the impedance voltage and corresponding load loss measured with rated current in the winding [*see also* IS 2026 (Part 8)].

Let

I = rated current in winding excited;

E = rated voltage of winding excited;

I_{sc} = current measured in winding excited

E_{zsc} = voltage measured across winding excited (impedance voltage);

P_{sc} = watts measured across winding excited

E_{xsc} = reactance voltage = $\sqrt{E^2_{\text{ZSC}} - \left(\frac{P_{SC}}{I_{SC}}\right)^2}$

P = P_{SC} corrected to 75 °C, and from current I_{sc} to I;

$$E_x = E_{XSC} \times \frac{I}{I_{sc}}$$

$$E_r = \frac{P}{I}$$

D-1.2 For rated load at unity power factor, the percentage regulation is approximately equal to

$$E_r\% + \frac{(E_x\%)^2}{200}$$

$E_x\% = 100\ E_x/E$;

$E_r\% = 100\ E_r/E$

$n = I_a/I$; and

I_a = current in the winding excited during the short circuit tests corresponding to that obtained when loading at the assumed load on the output side and with rated voltage on the input side.

D-1.3 For rated load any power factor cosφ, the percentage regulation is approximately equal to:

$$Er\% \cos\phi + Ex\% \sin\phi + \frac{(Ex\% \cos\phi - Er\% \sin\phi)^2}{200}$$

D-1.4 For any assumed load other than rated load and unity power factor, the percentage regulation is approximately equal to:

$$n.Er\% + \frac{(n.Ex\%)^2}{200}$$

D-1.5 For any assumed load other than rated load and at any power factor cosφ, the percentage regulation is approximately equal to:

$$n.Er\% \cos\phi + n.Ex\% \sin\phi + \frac{(n.Ex\% \cos\phi - n.Er\% \sin\phi)^2}{200}$$

D-1.6 The above formulae are sufficiently accurate for transformers covered by this specification.

ANNEX E

(*Clause* 22.1)

INFORMATION REQUIRED WITH ENQUIRY AND ORDER

E-1 NORMAL INFORMATION

The following information should be given in all cases:

a) Particulars of the specification to be complied with;

b) Application of Transformer for example normal Distribution Transformer, Solar duty, wind application, Motor starting etc.

c) Single or three phase unit;

d) Number of phases in system;

e) Frequency;

f) Indoor or outdoor type;

g) Type of cooling (KNAN);

h) Rated power (in kVA)

j) Rated voltages (for each winding);

k) State if tappings are required and if on-load or off-circuit tap-changers, or links are required.

m) Highest voltage for equipment (for each winding);

n) Method of system earthing (for each winding);

p) Insulation level (for each winding), power frequency test level/impulse level;

q) Connection symbol;

r) Neutral terminals, if required (for each winding) and their insulation level to earth;

s) Special requirements of installation, assembly, transport and handling;

t) Fittings required and an indication of the side from which meters, rating plates, liquid-level indicator, etc. may be readable and

u) Natural ester liquid or synthetic organic ester liquid.

E-2 SPECIAL INFORMATION

The following additional information may be required to be given:

a) If a lightning impulse voltage test is required, whether or not the test is to include chopped waves [*see* IS 2026 (Part 3)];

b) Impedance voltage at rated current, if specific value is required;

c) Altitude above mean sea-level, if in excess of 1 000 m;

d) Whether transformers will be subjected to frequent overcurrent, for example, furnace transformers and traction feeding transformers;

e) Any other exceptional service conditions;

f) Whether noise level measurement is to be carried out;

g) Vacuum withstand of the transformer tank, if a specific value is required;

h) Type of Tap-changer controls required (if OLTC is provided);

j) Type of mounting for example pole mounted, ground mounted etc.; and

k) Any other appropriate information, including reference to any special tests not referred to above which may be required.

ANNEX F

(*Clauses* 21.2 (j), 21.5.1.3, 21.5.2.3 *and* 21.5.3.3)

ADDITIONAL INFORMATION ON LEAKAGE TEST

F-1 Calculation of Gauge pressure during ester liquid leakage test from Normal static head

Hydrostatic pressure in liquid is given by:

$$P = \rho g h$$

where

P = Pressure at a point (Pa);

ρ = Density of liquid (kg/m^3) (Ref. relevant standard or supplier's test certificate);

g = acceleration due to gravity (9.81 m/s^2); and

h = height of liquid column at a particular point (m) (measured from top).

F-2 As per **21.5.1.3**, **21.5.2.3** and **21.5.3.3**, the amount of pressure application during the leakage test on assembled transformer for non-sealed and sealed type transformers with all fittings including bushing in position is summarized below:

a) *Tank without corrugations* — Pressure equivalent to twice the normal head measured/calculated at base of tank for 8 h (for 3 phase transformer) and 6 h (for 1 phase transformers)

b) *Tank with corrugations* — 15 kPa measured at top of the tank for 6 h for both 3 phase and 1 phase transformer.

F-3 If position of pressure gauge is not specified, based on facility available, the pressure gauge can be mounted near the base of the tank or near the top cover (or on the cover):

a) The depth of static head at bottom gauge position shall be the height from highest liquid level to base of tank; and

b) The depth of static head at top of the tank shall be the height from highest liquid level in conservator up to tank top gauge location.

In case the conservator is not provided, (for example, single phase transformers and small 3 phase transformer below 63 kVA) and pressure gauge is mounted on cover of tank, a pressure equivalent to one static head (tank height in this case) shall be applied since as per requirement test pressure is equivalent to twice the static head.

F-4 Sample calculation of pressure for a transformer having ester liquid level of 1000 mm:

Density of ester liquid, ρ = 1.0 g/cc = 1000 kg/m^3

Ester liquid level in the T/F, h = 1000 mm = 1 m

Hence, normal head pressure = (1000 × 9.81 × 1) Pa = 9810 Pa ≈ 9.81 kPa

Twice the normal head pressure = 2 × 9.81 kPa = 19.62 kPa

Hence, Pressure to be measured in the gauge is,

a) 19.62 kPa, if gauge is fixed at base of tank; and

b) 9.81 kPa, if gauge is fixed at top.

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